Section 7

Individual Species in the Deep Sea

Organisms That Live in the Deep Sea

There are a number of activities on the Ocean Exploration web site that target the characteristics and adaptations of individual deep ocean species. This curriculum has elected to focus on the most unique—those of the hydrothermal vents and cold methane seeps. This barely scratches the surface with regard to examining ocean biodiversity, but these two communities include many members of common groups of vertebrates and invertebrates such as bony fish and sharks; sea stars, brittle stars and sea cucumbers; amphipods, crabs, isopods, lobsters and shrimp; octopods, mussels and clams; and many kinds of worms. The third exercise used here, *InVENT a Deep-sea Invertebrate*, enables students to explore this wide range of species while the first two focus on the giant tubeworms—the animals that blew scientists' minds on the first deep vent expedition in 1977. These two exercises, *Let's Make a Tubeworm* and *This Old Tubeworm*, include details about the unique biology of these strange worms.

Deepwater Corals Versus Stony Corals

Several of the expeditions (Deep East 2001 and Northwestern Hawaiian Islands 2002 among them) have examined deepwater corals for distribution, abundance, biochemical composition and trawl fishing impact. The term coral needs clarification for most people. Many organisms in the phylum Cnidaria have the word coral as part of their common name. This implies a relationship that does not exist among these species. Most biologists use the term coral to refer to reef-building stony corals that possess endosymbiotic, single-celled dinoflagellate algae called zooxanthellae within their inner cell layer. These stony corals deposit calcium carbonate skeletons underneath themselves, forming increasingly massive stony structures called coral reefs that may have more than a mile of calcium carbonate beneath them on some slowly sinking Indo-Pacific seamount atolls.

Reefs—Coral or Rocky

The word reef refers to any rocky substrate that rises above the ocean floor. Hence, in a coral reef, the hard substrate is calcium carbonate from coral skeletons and coralline algae. A number of OE activities refer to reef fish and reefs off the southeastern United States well out of the range of reef-building corals. In this case, the reef is rock, and the corals associated with it are deepwater corals and non reef-building stony corals.

Stony Corals

Stony corals are not particularly similar to deepwater corals except for possessing the characters common to all members of the Cnidaria—polyps (or medusae which are upside down free-living polyps) and cnidoblast stinging cells containing nematocysts. Stony corals are restricted to shallow water since their algae require light. Their biology, structure and growth forms differ greatly from that of deepwater corals. Since they are easily and extensively studied with SCUBA, they have not been the focus of any Ocean Exploration expeditions.

Octocorals

Deepwater corals are mostly octocorals, having 8 featherlike tentacles. Many have a skeleton of protein and calcium carbonate spicules that is often tree-like in growth form and flexible. The connections among octocoral polyps are inside this skeleton, and the polyps extend out from it. There are a number of octocoral orders. Shallow water octocorals such as sea fans and sea whips as well as deepwater members occur among these orders. Brightly colored, flexible, branched octocorals are common along temperate beaches after storms. Deepwater octocorals growth attached to hard surfaces forming hard bottom communities that give food and shelter to large numbers of invertebrates and fishes. Trawl fishing, with nets that drag along the bottom, can destroy this sheltering structure and the homes it provides to the very species the fishers are targeting.

Other Deepwater Corals

There are also deepwater corals that are non-reefbuilding stony corals that produce very modest calcium carbonate skeletons, tropical black corals with horny skeletons and tree-like growth form, and hydrocorals which are hydrozoans that deposit exquisitely beautiful and fragile rigid calcium carbonate skeletons around their colonial polyps.

Bioprospecting

Bioprospecting, searching for potentially useful natural biochemical products that may have medical or other commercial value, targets many lesser-known marine species—bacterial, algal and invertebrate. These biologically-active chemicals were selected for by harsh environments and strong predation. A number of the Ocean Exploration expeditions include scientists who are bioprospecting for new valuable chemical products. If samples taken prove interesting, bench chemists can often synthesize the same compound in the lab for further testing and commercial production.

Classroom Activities in this Section

The activities in this section build on information and exercises done in earlier sections, applying earth and physical science to an understanding about the biology of specific ocean species. You may need to refer to earlier sections for content if you are using these exercises as independent pieces. If you are working your way through the materials in the order presented, your students will have the background needed to perform well on this section.

Where to Find More Activities on Individual Species in the Deep Sea

Ocean Exploration biology activities not included here, but found on the OE web site or CD include:

- *Deep Sea Coral Biodiversity*, *Design a Deep-sea Invertebrate or Vertebrate*, *Coral Mania* and *What's New?*

From Deep East 2001
- *One Tough Worm* from the 2002 Gulf of Mexico expedition
- *Spawn*, *Reproductive Lottery* and *Drifting Downward* from Islands in the Stream 2002
- *Survivors on the Ocean Ridge* from the 2002 Galapagos Rift expedition
- *The Odd Couple* from the Northwestern Hawaiian Islands 2002

Lesson Plan 18

Let's Make a Tubeworm!

Focus
Unique species with a symbiotic relationship in cold-seep communities

Focus Question
How do deep-sea tubeworm adaptations, including a symbiotic relationship with chemosynthetic bacteria, enable the worms to survive?

Learning Objectives
Students will describe the process of chemosynthesis in general terms.

Students will describe the major features of cold seep communities.

Students will define mutualistic symbiosis and give two examples of symbiosis in cold seep communities.

Students will be able to describe the anatomy of vestimentiferans and explain how these organisms obtain their food.

Materials
❒ A variety of art supplies, including cardboard tubes (mailing tube or paper towel roll), colored markers, pipe cleaners (to simulate tentacles), modeling clay, paper and glue

Audio/visual Equipment
None

Teaching Time
Two 45-minute class periods and homework

Seating Arrangement
Groups of four students

Key Words
Cold methane seeps
Hydrothermal deep vents
Chemosynthesis
Vestimentifera
Trophosome
Plume
Vestimentum
Trunk
Tube
Opisthosome

Background Information
Hydrogen sulfide is abundant in water erupting from hydrothermal vents as well as from cold methane seeps (see the Ocean Geologic Features section of this Curriculum for details on these geologic features). Bacteria that use the energy in hydrogen sulfide to support their metabolism are referred to as chemosynthetic bacteria. They form the basis of much of the food chain in both deep vents and seeps (see the Ocean Primary Production section for details). They may exist as free-living bacteria in clumps that are grazed upon by a variety of animals. Alternately, chemosynthetic bacteria live inside of animals in a mutualistic symbiotic relationship in which the animals support the existence of the bacteria and the bacteria provide food to the animals. One of the most interesting and unusual mutualistic symbiotic relationships exists between chemosynthetic bacteria and large tubeworms that belong to the group Vestimentifera. These very large worms were one of the most startling

discoveries associated with original exploration of hydrothermal vents and were subsequently found at cold methane seeps. They were originally classified within the phylum Pogonophora. More recently some taxonomists have placed the pogonophorans in the phylum Annelida.

Pogonophora means "beard bearing," and refers to the fact that many species in this phylum have one or more tentacles at their anterior end. Tubeworms living in the vicinity of hydrothermal vents and cold seeps are classified as vestimentiferans. Their tentacles are bright red from hemoglobin—the same molecule that carries oxygen and makes our blood cells red. Vestimentiferans can grow to more than 10 feet long and may live in clusters of millions of individuals. Some live more than 100 years. They do not have a mouth, stomach, or gut. Instead, they have a large organ called a trophosome that contains chemosynthetic bacteria. Hemoglobin in the tubeworm's blood absorbs hydrogen sulfide and oxygen from the water around the tentacles. Then the hemoglobin transports these raw chemicals to bacteria living in the trophosome. These bacteria produce organic molecules that provide nutrition to the tubeworm.

Similar symbiotic relationships are found in clams and mussels that have chemosynthetic bacteria living in their gills. A variety of other organisms are also found in cold seep communities, and probably use tubeworms, clams, mussels, and bacterial mats as sources of food. These organisms include snails, eels, sea stars, crabs, lobsters, isopods, sea cucumbers, and fishes. Specific relationships between these organisms are not well-studied. Likewise, there are whole communities of invertebrates and fish that depend on chemosynthetic bacteria around hydrothermal deep vents.

The Ocean Exploration 2002 Gulf of Mexico Expedition and the Galapagos Rift Expedition of 2002 both explored the unusual anatomy and ecology of vestimentiferans.

Learning Procedure

1. If you have not done so during previous classes, lead a discussion of deep-sea chemosynthetic communities. Contrast chemosynthesis with photosynthesis. In both, organisms build sugars from carbon dioxide and water. This requires energy. Photosynthesizers use energy in sunlight, while chemosynthesizers obtain energy from chemical reactions. Contrast hydrothermal vent communities with cold-seep communities. Visit http://www.bio.psu.edu/cold_seeps for a virtual tour of a cold seep community, including several tubeworm pictures.

2. Challenge the groups of students to produce the most accurate model of a vestimentiferan tubeworm, using Internet sources for information. Students may visit http://www.cham.montefiore.org/links/pbs/wgbh/nova/abyss/life/tubewormsans.html for an illustration of tubeworm anatomy and explanations of what each body part does.

3. Have each student group create a three-dimensional model of a tubeworm from materials you supply or those they find themselves. A portion of the model should be in cut-away form so that internal structures are displayed. The following structures should be included:
   - plume (including red color to indicate hemoglobin)
   - vestimentum
   - trophosome (including symbiotic bacteria)
   - trunk
   - tube
   - opisthosome

4. Have each group prepare a written report that includes:
   - a description of the function of each of the organs or structures listed above;
   - a description of the symbiotic relationship between the tubeworm and chemosynthetic bacteria;

- an explanation of how the tubeworm obtains its food;
- a discussion of how this symbiotic relationship supports other organisms in the cold seep food web and what some of these organisms might be.

5. Have the students compare models during group reports to the class. They might have a secret ballot to determine which is the most accurate. If you have more than one section, have sections vote on another class' models.

The BRIDGE Connection

www.vims.edu/BRIDGE/vents.html

The "Me" Connection

Have students write a short essay on symbiotic relationships that are important in their own lives.

Connection To Other Subjects

English/Language Arts, Earth Science

Evaluation

Models and the accompanying written reports can be evaluated on the basis of the extent to which the required elements are included, the quality of the written discussions and the scientific accuracy of the sites they selected for information.

Extensions

Have students draw a cold seep food web that includes at least six organisms representing primary producers and consumers.

Resources

http://oceanexplorer.noaa.gov – the 2002 Gulf of Mexico Expedition daily documentaries and discoveries.

http://www.bio.psu.edu/People/Faculty/Fisher/fhome.htm – Web site for the principal investigator on the 2002 Gulf of Mexico expedition.

http://www.rps.psu.edu/deep/ – Notes from another expedition exploring deep-sea communities.

http://ridge.oce.orst.edu/links/edlinks.html – Links to other deep ocean exploration web sites

http://www-ocean.tamu.edu/education/oceanworld/resources/ – Links to other ocean-related web sites.

http://www.cham.montefiore.org/links/pbs/wgbh/nova/abyss/life/tubewormsans.html

This activity was based on:

Paull, C.K., B. Hecker, C. Commeau, R.P. Feeman-Lynde, C. Nuemann, W.P. Corso, G. Golubic, J. Hook, E. Sikes, and J. Curray. 1984. Biological communities at Florida Escarpment resemble hydrothermal vent communities. *Science* 226:965-967 – an early report on cold seep communities.

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science

- Transfer of energy

Content Standard C: Life Science

- Structure and function in living systems
- Populations and ecosystems
- Diversity and adaptations of organisms

Content Standard D: Earth and Space Science

- Structure of the Earth system

Activity developed by Mel Goodwin, PhD, The Harmony Project, Charleston, SC

Lesson Plan 19

This Old Tubeworm

Focus
Growth rates and ages of species in cold-seep communities

Focus Question
What are the growth rates and longevity of cold seep organisms?

Learning Objectives
Students will construct a graphic interpretation of age-specific growth from data on incremental growth rates of different sized individuals of the same species.

Students will estimate the age of an individual of a specific size from data on age-specific growth in individuals of the same species.

Materials
❒ A copy of *Lamellibrachia Growth Rate Data Sheet* and *Growth Data Worksheet* for each group

Audio/visual Equipment
None

Teaching Time
One or two 45-minute class periods

Seating Arrangement
Groups of four students

Key Words
Cold methane seeps
Chemosynthesis
Vestimentifera
Trophosome
Growth rates
Longevity

Background Information
This exercise should follow *Let's Make a Tubeworm* and assumes the students have studied tubeworm anatomy and ecology. While there are many similarities between biological communities associated with hydrothermal vents and cold-seeps, there are also some important differences. One of these is that the physical environment of vent communities can change dramatically over a short period of time. Highly acidic water as hot as 400°C may suddenly erupt, accompanied by large amounts of toxic hydrogen sulfide. Vent organisms adapted to this rapidly changing environment often have growth rates that are much higher than those seen among organisms living in other deep-sea communities.

Things are different in cold-seep communities where the slow, steady release of methane and other hydrocarbon compounds provides a much more consistent environment. Yet, some species characteristic of cold-seep communities are quite similar to species found in vent communities. Tubeworms, for example, are abundant in both communities and have similar symbiotic relationships with chemosynthetic bacteria. Tubeworms in vent communities are among the fastest-growing invertebrates on the planet and reach a large size in relatively few years. Do tubeworms in cold seep communities also have rapid growth rates? How old are the largest tubeworms in cold seep communities? These are questions asked by biologists on the 2002 Gulf of Mexico expedition and are the subject of this activity.

Learning Procedure

1. If necessary review deep-sea chemosynthetic communities. Contrast chemosynthesis with photosynthesis. Point out that there are a variety of chemical reactions that can provide energy for chemosynthesis. Visit http://www.bio.psu.edu/cold_seeps for a virtual tour of a cold seep community and http://www.bio.psu.edu/hotvents for a virtual tour of a hydrothermal vent community. Have the tube-worm models in the classroom for reference.

2. Give a *Lamellibrachia* Growth Rate Data Sheet to each group. Explain that these are results taken from studies on vestimentiferans at two cold-seep sites in the Gulf of Mexico. In these studies, the worm's outer tube was marked with a blue stain. After one or more years, stained individuals were collected and new tube growth was measured as the length of the unstained segment of the tube between the stain mark and the end of the worm. Have each group plot growth rate (y-axis) as a function of length of the worm (x-axis). Students should draw a curve that passes through or near as many data points as possible.

3. Discuss the plotted data. These graphs show that the tubeworms' growth rates slowed as the size of the animals increases. This is common among most species of animals.

4. Next students will estimate the age of the largest animals. The researchers did this by fitting a curvilinear regression line to the data, then integrating the growth equation over the interval. An alternative, but less precise, approach can be used to estimate an approximate age. This approach involves breaking an animal's growth history into a series of intervals, determining how long it took to grow through each interval, then adding these individual growth times together to arrive at an approximate age (integration is based on a similar approach for a nearly infinite number of intervals). The curve drawn in Step #2 represents the growth history of an "average" tubeworm, based on growth data from 35 individual tube-worms. This curve will be used to estimate the age of a tubeworm 200 cm long.

5. Distribute one *Growth Data Worksheet* to each group. The first interval to be considered is 0 - 10 cm. Have students use their plots from Step #2 to find the predicted growth rates (in cm per year) at size = 0 cm and size = 10 cm. Tell students to find the average of these two numbers, and assume that this average represents how fast the animal was growing between the sizes of 0 and 10 cm. Now, calculate how long (in years) it would take to grow 10 cm by dividing 10 cm by the average growth rate (cm/yr). Round answers to the nearest tenth of a year and enter the result in the last column of the worksheet. Repeat this process for the remaining intervals (10 - 20 cm, 20 - 30 cm ....190 – 200 cm), finding the average growth rate for the interval, calculating how long it would take the animal to grow that 10 cm, and entering the result in the last column of the worksheet. Add all of the entries in the last column of the worksheet to find the total time required to grow through all intervals from 0 through 200 cm. This sum is the estimated age of a tubeworm whose length is 200 cm.

6. Have each group present its results. Each group will probably be somewhat different due to the need to estimate intermediate points on the graphs. The overall trend, however, should show that a 200 cm tubeworm from the sites studied would be over 200 years old. Discuss these results, asking students whether it is reasonable to suppose that tubeworms could be this old. Why not; after all, how much do we really know about average life expectancy among deep-sea organisms? Ask what factors might contribute to this longevity, such as a very stable environment and absence of many predators or competitors because of extreme conditions to which these animals are uniquely well adapted. Is it likely that other species could also be relatively old, compared to similar

species in other communities? Again, why not, since the factors that might help tubeworms live for a long time could also help other species do the same. Ask students why there should be such a striking difference in growth rates between tubeworms at hydrothermal vents and cold seeps. Vent communities exist in very dynamic conditions, and things may change dramatically at any time. Cold seep communities are based on slow leakage of hydrocarbon materials from beneath the sea floor and probably do not experience much change over very long periods of time.

The BRIDGE Connection

www.vims.edu/bridge/vents.html

The "Me" Connection

Have students write a short essay contrasting life in two communities. The first community exists in a remote valley where weather patterns and local physical conditions combine to produce a very stable and livable climate that remains virtually unchanged from year to year. The other community exists in a region that frequently experiences significant volcanic activity, including eruptions of poisonous gases and superheated air. Students may assume that the first community offers unusually long life-spans to individuals living there, while the second community offers unusually rapid growth and maturation of individuals (couples typically have their first child at the age of 7), as well as the prospect of sudden and unpleasant death at any time.

Connection To Other Subjects

English/Language Arts, Earth Science

Evaluation

Have students prepare individual written interpretations of their results prior to oral presentations in Step #6.

Extensions

Have students investigate growth studies in other ocean communities and develop hypotheses for why growth and longevity vary among these communities.

Resources

http://oceanexplorer.noaa.gov – 2002 the Gulf of Mexico Expedition documentaries and discoveries.

http://www.bio.psu.edu/People/Faculty?Fisher/thome.htm – web site for the principal investigator on the 2002 Gulf of Mexico expedition.

http://www.rps.psu.edu/deep/ – notes from another expedition exploring deep-sea communities.

http://www.ridge.oce.orst.edu/links/edlinks.html – links to other deep ocean exploration web sites

http://www-ocean.tamu.edu/education/oceanworld/resources/ – links to other ocean-related web sites.

Based on papers by:
Paull, C.K., B. Hecker, C. Commeau, R.P. Feeman-Lynde, C. Nuemann, W.P. Corso, G. Golubic, J. Hook, E. Sikes, and J. Curray. 1984. Biological communities at Florida Escarpment resemble hydrothermal vent communities. *Science* 226:965-967 – Early report on cold seep communities.

Bergquist, D. C., F. M. Williams, and C. R. Fisher. 2000. Longevity record for deep-sea invertebrate. *Nature* 403:499-500. – Technical journal article upon which this activity is based.

National Science Education Standards

Content Standard A: Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science
- Chemical reactions

Content Standard C: Live Science
- Interdependence of organisms

Activity developed by Mel Goodwin, PhD, The Harmony Project, Charleston, SC

Student Handout

Lamellibrachia Growth Rate Data Sheet

Length of Tubeworm (cm)	Growth Rate (cm per year)
5	4.75
10	4.25
10	4.75
10	3.75
20	4.25
20	3.60
20	3.00
30	3.20
30	2.80
40	2.75
40	3.00
50	2.00
50	2.75
50	2.40
60	2.00
70	2.25
70	1.25
80	1.50
90	1.75
90	0.75
100	1.25
110	1.00
120	0.75
130	0.75
130	1.00
130	0.50
150	0.50
150	0.75
150	0.25
170	0.50
170	0.10
180	0.70
180	0.10
200	0.05
200	0.45

Student Handout

Growth Data Worksheet

Growth Interval (cm)	Growth Rate at Beginning of Interval (cm/yr)	Growth Rate at End of Interval (cm/yr)	Average Growth Rate (cm/yr)	Time to Grow 10 cm (yr)
0 – 10				
10 – 20				
20 – 30				
30 – 40				
40 – 50				
50 – 60				
60 – 70				
70 – 80				
80 – 90				
90 – 100				
100 – 110				
110 – 120				
120 – 130				
130 – 140				
140 – 150				
150 – 160				
160 – 170				
170 – 180				
180 – 190				
190 – 200				

TOTAL TIME TO REACH 200 CM ____________________

Lesson Plan 20

InVENT a Deep-Sea Invertebrate

Focus
Adapations to deep sea conditions

Learning Objectives
Students will design an invertebrate capable of living near deep-sea hydrothermal vents.

Students will describe the unique adaptations that organisms must have in order to survive in the extreme environments of the deep sea.

Materials
- ❒ Reference materials – CDs, invertebrate and vertebrate textbooks, Internet access
- ❒ Colored pencils or markers (one pack per student group)
- ❒ *Animal Adaptation Chart* (one copy per pair of students)
- ❒ Chart paper

Teaching Time
Two 45-minute sessions

Seating Arrangement
Students work in pairs for research

Key Words
Benthic
Adaptations
Hydrothermal vent
Chemosynthesis
Photosynthesis
Carbohydrates
Ecosystems
Tubeworm
Invertebrate
Amphipod
Sessile

Background Information
More than twenty-five years ago, Jack Corliss, Robert Ballard, and other Woods Hole Oceanographic Institution oceanographers first observed a hydrothermal vent system near the Galapagos Islands on the Galapagos Rift. The year was 1977. They amazed the world with the discovery of communities of organisms that were unique. These communities were extremely dense near the vents—a surprise because deepwater benthic communities are usually quite dispersed and have low biomass since things living on the bottom are dependent upon food that falls from above in the photosynthetic zone. The explanation for the high biomass in vent communities came with the discovery that bacterial chemosynthesis was the basis of the food web. Since this initial discovery, numerous other hydrothermal vent systems have been located in the Pacific, Atlantic, and Indian Oceans.

Animals living in hydrothermal vent communities have unique adaptations to a challenging set of environmental conditions. Hydrothermal vents occur where seawater erupts up through the cracks between plates of the Earth. Fresh lava flows are common here. Hydrothermal vents are created by water penetrating into these cracks. Seawater percolates deep into the oceanic crust, super heats, rises and returns to the ocean floor at temperatures as high as 400°C. The surrounding ocean water is about 2°C and is under extreme pressure which prevents the vent water from boiling. Vent water contains dissolved metal ions of iron, magnesium, copper, and zinc. Hydrogen and hydrogen sulfides are also dissolved in the hot vent plumes, along with metallic ions and metallic salts. The metals precipitate out, forming vent chimneys. Hydrogen sulfides may precipitate within the latticework of the vents. Chemosynthetic bacteria synthesize carbohydrates, using hydrogen sulfides, water and oxygen. They are the primary producers of the vent food chain. They may live as colonies or mats or as endosymbionts within animals. The vent organisms are exposed to extreme temperatures, wide pH ranges, very high pressure, and total darkness.

Like all organisms, vent animals have adaptations that enable them to live and reproduce in this extreme environment. Adaptations are inherited characteristics that help organisms live under specific sets of conditions. Adaptations include physical characteristics such as body shape, anatomical features, ways of moving, feeding mechanisms, protective characteristics, and reproductive strategies. They may also be biochemical such as enzymes adapted to higher than normal temperatures or the ability to metabolize unusual substrates. They may also be behavioral traits.

Scientists have discovered over 300 new species associated with vent communities. Perhaps the most notable are the giant tubeworms, which can reach 6 feet in length—the fastest growing invertebrates known. Other worms, like the Jericho worm, are about the size of a pencil and live in tubes that look like accordions. Organisms adapted to vent living include clams, mussels, and shrimp. Amphipods, small lobsters, sea anemones, fish, and octopi have also been found in these extreme environments. Each time scientists explore a new rift system, they discover new species.

Learning Procedure

1. Ask students to list all of the challenges to living things that occur in the area of a deep hydrothermal vent. You may give them a set time to explore reference materials. Then list these on the board. Some are listed above: pressure, lack of light, primary production carried out by chemosynthetic bacteria, cold surrounding water, superheated vent water, extreme pH, toxic dissolved metals and hydrogen sulfides.

2. Discuss the concept of an adaptation—an inherited, genetically-controlled characteristic that enables an organism to be suited to a specific environment or do something unique. Individuals do not adapt, they inherit their adaptations. The environment selects those individuals with the genetics that most fit their environment to reproduce and pass on those characteristics. Brainstorm with your students about the kinds of adaptations that organisms might need to live in the extreme conditions associated with hydrothermal vent ecosystems. Record these answers on the board.

3. Have each student pair research organisms found in or near hydrothermal vent communities, using available references such as the Internet, encyclopedias, and/or textbooks, including: www.divediscover.whoi.edu

4. Give a copy of the *Animal Adaptation Chart* to each pair. Challenge them to design and draw an invertebrate capable of living in or near a hydrothermal vent ecosystem. Each invertebrate should exhibit adaptations in body form (for both young and adult stages), locomotion, feeding, and protection. The pair should name their "new" organism and designate the taxonomic group to which it belongs.

5. The students may be asked to describe to the class, as they display the drawing, what their organism's body shape is and why it is shaped that way, how it moves, how it feeds, how it protects itself, what its young look like and why they might look the way they do.

The BRIDGE Connection

http://www.vims.edu/bridge/vents.html

The "Me" Connection

Ask students to think about what types of adaptations would be useful to humans if the temperature of the air were to rise such that desert conditions existed everywhere on Earth. Examples might be nocturnal habits, large ears for heat loss, nostrils and lungs that conserved water, etc.

Connection To Other Subjects

Art, English/Language Arts

Evaluation

Charts from each student pair may be evaluated for completeness and student drawings may be evaluated for understanding of adaptations.

Extensions

Have your students visit http://oceanexplorer@noaa.gov and www.divediscover.whoi.edu with a family member to check the latest hydrothermal vent discoveries.

Have students write a story about "A Day in the Life of..." for the animal they designed. They should explain the unique adaptations of the animal within the story.

The student pairs could get together with other student pairs to form a food web that incorporates several of the animals they designed.

Resources

http://oceanexplorer@noaa.gov

www.divediscover.whoi.edu

National Science Education Standards

Life Science Content Standard C:

- Structure and function in living systems
- Reproduction and heredity
- Regulation and behavior
- Populations and ecosystems
- Diversity and adaptations of organisms

Activity adapted from Design a Deep Sea Invertebrate, developed by Robin Sheek and Donna Ouzts, Laing Middle School, Charleston SC

Student Handout

Animal Adaptation Chart

Directions: Use references provided to complete the following chart for your invertebrate.

Draw a picture of your animal:

Describe its body form:

Describe how it moves:

Describe how it feeds:

Describe how it protects itself:

Describe what its young look like:

Lesson Plan 21

Invertebrate Chemists

Focus
Some benthic invertebrates produce pharmacologically-active substances

Focus Question
What groups of marine organisms produce substances that may be helpful in treating human diseases?

Learning Objectives
Students will identify at least three groups of benthic invertebrates that are known to produce pharmacologically-active compounds.

Students will describe why pharmacologically-active compounds derived from benthic invertebrates may be important in treating human diseases.

Students will infer why sessile marine invertebrates appear to be promising sources of new drugs.

Materials
❒ Marker board, blackboard, or overhead projector with transparencies for group discussions

Audio/Visual Materials
None

Teaching Time
One or two 45-minute class periods, plus time for student research

Seating Arrangement
Classroom-style or groups of 2-3 students

Key Words
Cardiovascular disease
Cancer
Arthritis
Natural products
Sponge
Tunicate
Ascidian
Bryozoan
Octocorals
Sessile

Background Information
Advances in medicine have resulted in longer average human life span. As infectious diseases such as polio, tuberculosis, and a host of childhood problems have been largely conquered by vaccination and antibiotics, medical research has focused more on cardiovascular disease and cancer which together account for more than 1.5 million deaths annually. These are much more complex, often occurring later in life and having both genetic and environmental causes. Additionally, one in six Americans have some form of arthritis, and hospitalized patients are increasingly threatened by infections that are resistant to conventional antibiotics. The annual cost of these diseases is high: $285 billion per year for cardiovascular disease; $107 billion per year for cancer; and $65 billion per year for arthritis. The economic value of new drugs that effectively treat these diseases or drug-resistant infectious agents is obvious.

Many drugs in use today originated as natural products. Aspirin, for example, was first isolated from the willow tree. Morphine is extracted from the opium poppy. Penicillin was discovered from common bread mold. To date, almost all of the drugs derived from natural sources come from terrestrial organisms. But recently, systematic searches for new drugs have shown that marine algae and invertebrates are a rich source of biologically-active chemicals that have antibiotic, anti-cancer, or anti-inflammatory properties. Particularly promising invertebrate groups include sponges, tunicates, ascidians, bryozoans, octocorals, and some molluscs, annelids, and echinoderms.

The list of potential drugs derived from marine invertebrates includes:
Ecteinascidin – Extracted from tunicates; being tested in humans for treatment of breast and ovarian cancers and other solid tumors

Topsentin – Extracted from the sponges *Topsentia genitrix*, *Hexadella* sp., and *Spongosorites* sp.; anti-inflammatory agent

Lasonolide – Extracted from the sponge *Forcepia* sp.; anti-tumor agent

Discodermalide – Extracted from deep-sea sponges belonging to the genus *Discodermia*; anti-tumor agent

Bryostatin – Extracted from the bryozoan *Bugula neritina*; potential treatment for leukemia and melanoma

Pseudopterosins – Extracted from the octocoral (sea whip) *Pseudopterogorgia elisabethae*; anti-inflammatory and analgesic agents that reduce swelling and skin irritation and accelerate wound healing

ω-conotoxin MVIIA – Extracted from the cone snail, *Conus magnus*; potent pain-killer

The 2003 Medicines from the Deep Sea Expedition focused on the discovery of new resources with pharmaceutical potential in the Gulf of Mexico. The expedition collected selected benthic invertebrates from deep-water bottom communities in the Gulf of Mexico (sponges, octocorals, molluscs, annelids, echinoderms, tunicates). These samples provide many months of lab work that starts with identification of the organisms. DNA and RNA samples are taken. Scientists then isolate and culture microorganisms that live in association with deep-sea marine invertebrates; prepare extracts of benthic invertebrates and associated microorganisms, and test these extracts to identify those that may be useful in treatment of cancer, cardiovascular disease, infections, inflammation, and disorders of the central nervous system. These tests are largely done in cell cultures. Chemists isolate unique products from those extracts that show pharmacological potential and determine the structure of these chemicals. This allows further study of the pharmacological properties of active compounds. Perhaps most important, scientists develop methods for the sustainable use of biomedically-important marine resources.

The last objective is particularly important, since many potentially useful drugs are present in very small quantities in the animals that produce these drugs. This makes it impossible to obtain useful amounts of the drugs simply by harvesting large numbers of animals from the sea. Some alternatives in addition to chemical synthesis of specific compounds are aquaculture to produce large numbers of productive species, or culture of the cells that produce the drugs. Natural products chemists have become extremely effective at copying new molecules in the lab which removes dependence on wild populations.

This activity is designed to familiarize students with some of the organisms that produce chemicals that have shown promise for the treatment of human diseases. Perhaps most important, it encourages students to think about the physical characteristics and environmental situations that result in the evolution of biologically-active chemicals in certain groups.

Learning Procedure

1. Ask the students to comment briefly without names on their relatives and friends, perhaps even themselves in relation to the value of finding new drugs for the treatment of cardiovascular disease, cancer, inflammatory diseases, and infections. Make a chart on the board listing each of these categories and ask for student hands indicating who has personal knowledge of someone with that category of disease. Discuss the economic value as well as the value of relief of suffering when a new drug is produced that effectively treats one of these diseases.

2. Briefly introduce the concept of drugs from natural products and describe the potential of marine communities as sources for these drugs. These are the objectives of the 2003 Medicines from the Deep Sea Expedition.

3. Challenge the students to do their own bio-prospecting on the Internet and prepare a written report on a marine benthic invertebrate that produces one or more substances having potential for treating human diseases. Reports should include:
   - description of the organism, with pictures if possible;
   - basic life history information about these organisms (where they live, what they eat)
   - students' inferences about how powerful chemicals might be useful to the organism.

   You may also want to ask students to find out about chemicals produced by their assigned organism that may be useful for treating human diseases.

   Assign each student group one or more of the following groups of organisms:

   sponges
   tunicates
   ascidians
   bryozoans
   octocorals

4. When the reports are done, have students make a brief oral presentation of their research results. Lead a discussion focusing on the role of pharmacologically-active substances to the organisms studied. Lead students to discuss the characteristics of these species that make having biologically-active compounds useful to them: discouraging predators by being distasteful or toxic; preventing faster growing organisms from over growing them by inhibiting the growth of competitors; warding off bacteria, fungi or parasites that cause disease by killing them or inhibiting their growth. Like plants that are a rich terrestrial source of drugs, these invertebrates are largely sessile - they are basically "sitting ducks." Have the students speculate on how each of the above might translate into a useful drug. For example, if two species were competing for space on which to grow, it would be helpful to produce a substance that would attack rapidly-dividing cells of the competing organism. Since cancer cells often divide more rapidly than normal cells, the same substance might have anti-cancer properties.

The BRIDGE Connection

www.vims.edu/bridge/ – Click on "Ocean Science" in the navigation menu to the left, then "Chemistry" for resources on drugs from the sea. Click on "Ecology" then deep sea for resources on deep-sea communities. Click on "Human Activities" then "Technology" then "Biotechnology" for resources on biotechnology.

The "Me" Connection

Have students write a short essay from the viewpoint of a sessile benthic invertebrate, describing the hazards their animal must face in a typical day, and how their animal is adapted to survive these challenges.

Connections to Other Subjects

English/Language Arts; Chemistry

Evaluation

Written and oral reports provide opportunities for evaluation.

Extensions

Log on to http://oceanexplorer.noaa.gov for discoveries from the 2003 Medicines from the Deep Sea Expedition.

Resources

http://oceanica.cofc.edu/activities.htm – Project Oceanica web site, with a variety of resources on ocean exploration topics

http://www.science.fau.edu/drugs.htm – An overview article on drugs from the sea

www.nci.nih.gov – Web site of the National Cancer Institute

http://www.woodrow.org/teachers/bi/1993/ – Background and activities from the 1993 Woodrow Wilson Biology Institute on biotechnology

http://www.denniskunkel.com/ – Web site containing hundreds of images taken with light and electron microscopes

National Science Education Standards

Content Standard A: Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard C: Life Science
- Structure and function in living systems
- Reproduction and heredity
- Diversity and adaptations of organisms

Content Standard F: Science in Personal and Social Perspectives
- Personal health
- Risks and benefits
- Science and technology in society

Activity developed by Mel Goodwin, Ph.D.
The Harmony Project, Charleston, SC